DØ Run IIb Silicon Sensors for Layers 2−5
Production Readiness Review

Committee Report

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1. Introduction

The committee members met with the DØ Run IIb Silicon Group at Fermilab on 6 March 2003 and reviewed sensor specifications, prototype testing, quality assurance, overall production readiness, and schedule. The charge to the committee and the agenda of presentations are appended.

2. General Comments

The overall sensor design is sound and the choice of only one detector type for Layers 2−5 greatly simplifies testing and production. We were impressed by the overall effort in sensor design and technical specifications, and by the detailed quality assurance program that is planned for the project. The committee was satisfied that the L2−5 sensors will be robust against radiation damage for the luminosities expected in Run IIb. Specific comments are discussed below.

2.1 Sensor Specifications

In general the committee felt that the sensor specifications were well designed and sufficient to ensure suitable detectors for the DØ experiment. Several issues arose which need to be clarified in discussions with Hamamatsu Photonics (HPK):

(a) The specification for the detector full depletion voltage is $V_{dep} < 300$ V. The absence of a lower limit could lead to large, undesirable mismatches between detectors in the tracker. A lower limit of $V_{dep} > 40$ V seems appropriate, but should be discussed with HPK to ensure no impact on cost.
(b) The specification of wafer warp less than ±25 μm is too stringent, and in practice it may be too difficult to achieve. This specification was not met for the prototype sensors. DØ should understand what the real specification should be. The final sensor warp might be less once the sensor is glued down. This should be investigated and quantified.
(c) HPK will not do whole−wafer visual inspections for open−circuits or short−circuits, so this part of the specification should probably be deleted.
(d) The mask alignment specification (±2.5 μm) is not stringent enough. Mask alignment of ±0.5 μm should be achieved in order to ensure proper metal−implant overlap.

(e) The average coupling capacitance was 105 pF, about 12 pF below the minimum specification. The measurement should be checked − the reason why the specification was not met should be identified and corrected, or the specification should be revised.

Recommendation: Make revisions to the specifications as appropriate based on the above points.

2.2 Sensor Testing and Quality Assurance

The committee found that, in general, the DØ QA plan is adequate to ensure timely testing and quality control for the sensors. The QA testing program is well designed and comprehensive. Testing will be done at Fermilab, Kansas State, and Stony Brook. Testing of the prototypes indicates very good quality of detectors from HPK.

Sensor AC scans, which measure coupling capacitance, showed an anomaly on some prototype sensors − a large region of apparent high coupling capacitance. This is probably due to surface charge effects. Modules should be built with suspect sensors to study this charge-up issue.

Discrepancies were found between DØ and HPK measurements. DØ found 23 bad strips on 28 sensors measured. Of these, 15 bad strips were not identified by HPK's measurements. While the absolute number of bad strips is small, these discrepancies raise concerns about the quality of the HPK measurements. It is important that HPK does thorough, reliable testing of all strips, since otherwise, re−working of modules will have to be done.

Recommendation: Discuss the discrepancies as soon as possible with HPK to understand the cause for each discrepancy. This will ensure the integrity of the HPK measurements, which are relied upon for identifying bad strips for the majority of sensors.

Fast feedback of QA test results to HPK is important. This is particularly critical when measurements show unusual sensor characteristics which may indicate problems in the processing.

Inconsistencies in some DØ measurements, particularly in the radiation damage measurements, were identified in the following areas:

(a) The coupling capacitance measured on a prototype sensor after irradiation was 85 pF, compared with 100 pF before irradiation. We suspect that this is a measurement problem, and that the true capacitance is in fact unchanged. The measurement should be repeated to understand this issue.
(b) The leakage current damage constant $\alpha = 1 \times 10^{-17}$ A/cm is much lower than the well known value, which raises questions about the dosimetry at the KSU irradiation facility.
(c) There are inconsistencies in the measurements of full depletion voltage after irradiation.
(d) Measurements of properties such as coupling capacitance and polysilicon resistance after irradiation were not done correctly.

The radiation damage issues are important to fully quantify, and this will be particularly critical for the L0 and L1 detectors.

Recommendation: The KSU facility's dosimetry needs to be fully understood and sensors should be irradiated at alternative facilities with well−understood dosimetry, such as the Indiana University cyclotron facility, the Fermilab Booster, or the Lowell neutron irradiation facility. The post−irradiation measurements need to be re−examined and fully understood.

Testing procedures at the three facilities should be fully developed well in time for the expected arrival of the first pre−production sensors. Each facility must have a local expert who fully understands the measurements and is responsible for the QA program.

Recommendation: Identify a physicist who is experienced with sensor device testing and properties to be responsible for the overall testing and QA program. This physicist should spend a significant fraction of his/her time on sensor QA, full−time if needed. Consistency of measurements between the different facilities should be ensured by selecting a subsample of detectors and comparing the results of the same QA tests performed at each facility.

Excellent progress has been made in module readout using prototype sensors, and results shown indicate fully functional modules with good signal−to−noise ratio. Some aspects of the noise performance are not well understood, especially the noise performance of irradiated sensors.

Recommendation: Perform refined SVX4 noise studies with prototype modules using 396 ns crossing time electronics to understand issues like setup noise and post−irradiation shot noise. We recommend DØ get together with CDF to understand the SVX4 noise behavior.

The sensor measurements are currently entered into a database which is based on MySQL. The basic structure for the database is sound and all data is accessible by all the testing sites. More work is needed to arrive at a fully functional database. The database has to allow entering of test data, and data delivered from HPK, and should ultimately become or be linked to the upgrade construction and simulation data base. Tasks such as the upload of HPK test data into the database need to be automated.

Recommendation: DØ should investigate if the database selected will serve the upgrade project smoothly through the entire project cycle. We recommend that this be done together with CDF and that databases of ongoing projects (CMS, ATLAS, GLAST) be investigated if the present choice is found deficient. DØ should ensure that there is adequate manpower allocated to maintain and extend the database. There should also be sufficient communication with the database users to ensure that the proper information is stored and is easily accessible.

2.3 Schedule

The purchase order for the L2−5 sensors is expected to be placed in March 2003. There are a total of 2016 sensors. It is expected that the first sensors will be received five months after the order is placed, and ganging of detectors will start in August 2003. Ganging can be done at a rate of 120 sensors/week.

HPK have said that they will deliver 200 sensors/week. In practice, due to processing load from other projects, sensors may be delivered in bursts so that in some months none are delivered and in other months 400 are delivered. This may put pressure on the ganging rate, which is limited by the number of CMMs at SiDet.

Communications with HPK must be smooth. The status of processing, numbers of detectors shipped, and numbers of detectors in various stages of processing should be provided regularly by HPK.

Recommendation: Obtain a firm commitment of the delivery schedule from HPK to clarify the delivery rate for each month of the project duration. DØ and CDF should work out a common delivery schedule with HPK, so that the schedule of both experiments is least impacted. An initial visit with HPK should be arranged (jointly with CDF) as soon as possible, and further visits during the sensor production may be necessary.

3. Overall Recommendation

The committee recommends that DØ proceed with the sensor order as quickly as possible, while pursuing the recommendations listed above.

Appendix A

Charge to Production Readiness Review Committee on the Layer 2−5 Sensors for the DØ Run IIb Silicon Sub−Project

J. Kotcher
DØ Run IIb Project Manager
02/25/03

The Committee is requested to review the overall readiness for placing the production order for the outer layer sensors for the DØ Run IIb silicon detector. In particular, the project is requesting that the Committee evaluate the following items:

- Whether the sensor specifications meet the technical requirements for Run IIb, recommending any changes that may be necessary. This should include a thorough review of results from the prototype tests, including those from radiation testing.

- The completeness and viability of the quality assurance program the project has in place to qualify the production−version outer layer sensors, including a review of:
    - Soundness of the logistics of the testing and qualification plan;
    - Technical specifications and criteria for quality assurance;
    - Adequacy of the resources, both labor and equipment, that have been requested in the project plan for testing and QA. Included here should be an evaluation as to whether the throughput of qualified sensors will be adequate to maintain the project schedule;
    - The adequacy of the plans for logging data from sensor testing.

- The overall technical readiness for placing the order, and the procurement readiness and strategy. If the Committee has any reservations here, it is requested that they describe what additional preparatory work should be done in order to meet proper readiness criteria.

- The outer layer sensors for both CDF and DØ are being produced in series, on a tight schedule, at the same vendor. The Committee is being asked to provide an opinion on whether the resulting vendor load and schedule should be of any concern. The Committee should also comment, to the extent it is able to do so, on the resulting demands on SiDet sensor testing facilities and associated labor that would be required in order to maintain the Run IIb schedule.

The review date has been set for Thursday, March 6 at Fermilab. As time is particularly tight, I would like to ask that the Committee submit a report summarizing their findings to me by Friday, March 14.

Once again, thank you very much. The contribution of your time and expertise is very much appreciated.

Appendix B

DØ Run IIb Silicon Sensors for Layers 2−5
Production Readiness Review

March 6, 2003
SiDet Conference Room

10:00am Committee Meeting
10:15am Short Project and Schedule overview −− Marcel Demarteau
10:30am Characterization of Sensors −− Marcel Demarteau
11:30am Characterization of Irradiated sensors −− Sergey Korjenevski

12:30pm −−Lunch−−

1:45pm Module Readout Performance −− Andrei Nomerotski
2:30pm Quality Assurance Program −− Regina Demina
3:15pm Committee Discussions